Hydrogeologic Framework of the Floridan Aquifer System in Florida and in Parts of Georgia, Alabama, and South Carolina

By JAMES A. MILLER

REGIONAL AQUIFER-SYSTEM ANALYSIS

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1403–B

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON: 1986

whay Formation. Fauna considered to characterize these two units include the Foraminifera *Pulvinulina mariannensis* Cushman, *Robulus vicksburgensis* (Cushman) Ellisor, *Palmula caelata* (Cushman) Israelsky, and *Globigerina selli* (Borsetti). The ostracode *Aurila kniffeni* (Howe and Law) is also considered characteristic of these strata.

Cooper Formation (Ashley Member)

The uppermost part of the Cooper Formation, called the Ashley Member by Ward and others (1979), is of Oligocene age, in contrast to the late Eocene age of the lower two members of the Cooper. The Ashley Member consists of brown to tan, soft, calcareous, clayey sand that usually contains much phosphate and glauconite and carries a rich microfauna. The thickness of the member is highly variable. To the south and southeast, the Ashley Member grades into the Suwannee Limestone by the addition of impure limestone beds and the loss of clastic strata. The microfauna of the Cooper were not examined in enough detail during this study to determine which species are characteristic of any of the formation's members, including the Ashley. However, the foraminifer *Pararotalia mexicana mecatepcensis* Nutall was identified from the upper part of the Cooper in several wells in northeastern Georgia.

Chandler Bridge Formation

The Chandler Bridge Formation (Sanders and others, 1982) is a thin sequence of clayey phosphatic sand beds that unconformably overlies the Ashley Member of the Cooper Formation. Chandler Bridge beds occur locally and appear to be preserved only in low areas on the Ashley surface. The Chandler Bridge contains no microfauna and is dated Oligocene on the basis of its stratigraphic position and the primitive aspect of its cetacean fauna, which somewhat resembles forms found in the upper Oligocene of Europe.

Depositional environments

The Suwannee Limestone and the equivalent thick sequence of unnamed interbedded limestone and dolomite in eastern panhandle Florida were deposited in a carbonate bank environment. The part of the Cooper Formation that is of Oligocene age (Ashley Member) and the Chandler Bridge Formation that overlies it were laid down in a marginal marine environment. All of the Oligocene units in Alabama and those in updip areas of panhandle Florida were deposited in shallow marine to restricted marine (lagoonal or estuarine) environments. The formations that are mostly limestones (Bumpnose, Marianna, and Glendon) formed in shallow, warm, open marine waters. Those units that are highly argillaceous and glauconitic (Red Bluff, Mint Spring, Byram, and Chickasawhay) are estuarine to lagoonal for the most part but may grade into shallow shelf, open marine deposits downdip. The dark-colored clays that are part of the Forest Hill and the updip portion of the Bucatunna are mostly lagoonal but in places may represent deltaic conditions. The Bucatunna and Forest Hill represent local regressive phases of the generally transgressive Oligocene sea.

MIOCENE SERIES

Rocks of Miocene age underlie most of the study area except for a wide band in northwestern peninsular Florida, where they have largely been removed by erosion. These strata are mostly clastic, with the exception of (1) sandy limestone that comprises the Tampa Formation and its equivalents and (2) dolomite beds that commonly make up the lower part of the Hawthorn Formation. Miocene rocks crop out over more of the study area than any other Tertiary unit and are highly dissected in outcrop and shallow subcrop locales. The paleogeography of the eastern Gulf Coast was very different in Miocene time than it had been before. The carbonate bank environment that characterized peninsular Florida and adjacent areas during most of Tertiary time was covered during the Miocene by an influx of clastic sediments. Chemical conditions in parts of the Miocene ocean were also quite different and resulted in the widespread deposition of phosphatic and siliceous sediments, especially during middle Miocene time.

The extent and the configuration of the surface of the Miocene Series is shown on plate 12, along with the area where these rocks crop out. Over more than half of their extent, Miocene rocks are at or above sea level. The contour interval used on plate 12 is smaller than that used on maps of the structural surfaces of older units to better portray the irregular topography developed on the top of the Miocene. The rough surface of the unit and the numerous small outliers preserved as erosional remnants apart from the main body of Miocene rocks show that the Miocene surface has been deeply eroded. At a few scattered places within the main body of Miocene rocks, older units are exposed where the Miocene has locally been completely eroded through.

In outcrop areas in Alabama and Georgia, Miocene rocks are found at altitudes of more than 300 ft above sea level. In south-central peninsular Florida, the Miocene top locally is at an altitude of more than 150 ft above sea level. The maximum measured depth to the top of the Miocene is about 1,360 ft below sea level in well ALA-BAL-30 in southern Baldwin County, Ala., and the maximum contoured depth of the unit is below 1,700 ft to the southwest of this well. Over much of south Florida, the Miocene top is 100 to 200 ft below sea level. Locally, along small faults in extreme southeastern Florida, the top of the unit has been dropped as much as 250 ft on the downthrown side of the faults. The only major structural features shown on plate 12 are a negative area in the southwestern tip of Florida that represents a part of the South Florida basin, and a steep gulfward slope of the Miocene top in southern Alabama produced by subsidence of the Gulf Coast geosyncline.

The thickness of the Miocene Series is shown on plate 13, as are those areas where the Tampa Limestone and its equivalents comprise part of the Miocene. The contours on this map are based primarily on well data. Certain features shown on this map, such as the small fault extending from Martin County to St. Lucie County in southeastern Florida, are taken from published sources. In areas of sparse control, the well-point data have been supplemented by subtracting contoured surfaces of the Miocene and Oligocene. Where Oligocene rocks are absent, the difference in altitude between the Miocene and late Eocene tops was used as a thickness approximation. Miocene strata thicken from a featheredge where they crop out to a thickness of more than 800 ft in southern Florida, more than 500 ft in southeastern Georgia, and more than 1,400 ft in southern Alabama. In a wide area across north-central peninsular Florida, Miocene rocks are very thin on the Atlantic side and absent to patchy on the Gulf side. This area of thinning generally coincides with an area where Oligocene rocks have been stripped (pl. 10) and where upper Eocene rocks are thin (pl. 9). The many local variations in the thickness of the Miocene shown on plate 13 are due to extensive erosion of the unit.

Although the Miocene rocks of the Southeastern United States have been studied in detail for many years, they remain poorly understood. This lack of understanding is due in part to the complexity of facies change within the rocks. For example, in western Florida, detailed work on somewhat scattered exposures of highly variable, shallow marine Miocene beds has resulted in a proliferation of "formations" whose extent and exact stratigraphic relations are poorly defined. Certain economic aspects of the Miocene, such as phosphorites and high-magnesium clays, have been closely scrutinized, but an economic study is likely to be of either local range or narrow focus. It is beyond the scope of this study to address the many problems of Miocene stratigraphy; therefore, the stratigraphic breakdown of the Miocene used herein is a general one (pl. 2). Greater detail on Miocene stratigraphy and various Miocene problems is presented in a collection of papers edited by Scott and Upchurch (1982).

The entire Miocene Series was mapped together as a single unit during this study. Microfauna that are considered characteristic of the undifferentiated Miocene in the study area include the Foraminifera *Amphistegina chipolensis* Cushman and Ponton, *A. lessoni* d'Orbigny, *Bolivina floridana* Cushman, *B. marginata multicostata* Cushman, *Elphidium chipolensis* (Cushman), and *Sorites sp.* Ostracoda considered characteristic of the Miocene include *Aurila conradi* (Howe and McGuirt) and *Hemicythere amygdula* Stephenson.

Tampa Limestone

The basal part of the Miocene Series in part of west-central peninsular Florida and much of the central and eastern parts of the Florida panhandle consists of the Tampa Limestone. As it is used in this report, the Tampa is a white to light-gray, sandy, hard to soft, locally clayey, fossiliferous (pelecypod and gastropod casts and molds) limestone that contains phosphate and chert in places. The phosphate content of the Tampa is low, however, in comparion with that of the overlying Hawthorn Formation. The mollusk remains in the Tampa vary from trace amounts up to 90 percent of the rock. Except for the sand and phosphate that it contains, the Tampa closely resembles the Suwannee Limestone. Some confusion exists in the literature as to the distinction between these formations, owing in part to the fact the Tampa-Suwannee contact is gradational in the type area of the Tampa (King and Wright, 1979). A difference of opinion also exists concerning the age of the Tampa. Certain mollusks from the unit are also found in the Paynes Hammock Formation of eastern Mississippi, once thought to be of early Miocene age but now known to be part of the Oligocene (Poag, 1972). Foraminifera from the Tampa, however, indicate that the formation is of early Miocene age, and the formation is placed in the early Miocene in this report.

From its type area in and around Tampa Bay, the Tampa Limestone grades southward into white, hard to semi-indurated, finely crystalline to micritic limestone that contains traces of sand, phosphate and scattered pelecypod casts and molds at irregular intervals. The basal part of this fine-textured limestone sequence consists largely of finely pelletal, micritic limestone. To the east and south, all these limestones become silty, clayey, and dolomitic and appear to grade into the lower part of the Hawthorn Formation.

The light-gray, sandy, pelecypod- and gastropod-rich lower Miocene limestone in the eastern and central parts of the Florida panhandle has been called the Tampa Limestone by some workers and the St. Marks Formation by others. This author could not distinguish between the Tampa and the St. Marks either in outcrop or in well cuttings, and all fossiliferous lower Miocene limestones in the study area are therefore called Tampa Limestone in this report. The Tampa in the Florida panhandle appears to pinch out against the Hawthorn Formation where it is overlapped by the latter unit. Marsh (1966) recognized that some limestones in the southern parts of Escambia and Santa Rosa Counties in extreme western Florida contain an early Miocene fauna, but he was unable to separate these strata from underlying limestone beds of the Chickasawhay Formation (Oligocene). This author agrees that a thin sequence of limestone is present near the Gulf Coast in these counties but, like Marsh, cannot consistently differentiate the Oligocene and early Miocene there. The thin carbonate sequence is thus mapped as part of the Oligocene in this report.

The Tampa Formation does not extend into Georgia. The beds that Counts and Donsky (1963) and Herrick and Vorhis (1963) called Tampa are in reality part of the basal Hawthorn, which consists largely of dolomite and dolomitic limestone.

The Catahoula Sandstone, a yellowish-gray sand and sandy clay unit that occurs locally in outcrop and in the shallow subsurface in Alabama, is thought to be a lower Miocene unit and therefore time equivalent to the Tampa. The two formations, however, are not connected. The Catahoula appears to grade into the lower part of the Hawthorn Formation. The Edisto Formation of South Carolina, a yellow-brown, sandy, fossiliferous limestone that occurs as erosional remnants on the top of the Cooper Formation, is also of early Miocene age but, like the Catahoula, is not connected to the Tampa Limestone.

Microfauna identified from the Tampa during this study include the Foraminifera *Amphistegina chipolensis* Cushman and Ponton, *Elphidium chipolensis* (Cushman), and *Sorites* sp. These species are not restricted to the Tampa, however, and are commonly found also in younger Miocene units.

Hawthorn Formation

The Hawthorn Formation is the most widespread and the thickest Miocene unit in the Southeastern United States. East of longitude 85° W, the Hawthorn constitutes most of the entire thickness of the Miocene strata shown on plate 13. The Hawthorn is a complexly interbedded, highly variable sequence that consists mostly of clay, silt, and sand beds, all of which contain scarce to abundant phosphate. Phosphatic dolomite or dolomitic limestone beds are common in the lower part of the formation. The argillaceous beds of the Hawthorn are usually green but locally are cream or gray. Hawthorn sands are light to dark brown where they are highly phosphatic and light green to gray where they carry only trace amounts of phosphate. The dolomite and limestone beds of the Hawthorn are most commonly brown but locally are cream to white. Most of the phosphate that occurs throughout the Hawthorn is fine to medium sand sized, but beds of pebble-sized phosphate are by no means rare, especially in the upper third of the formation.

Locally, the Hawthorn can be roughly divided (Carr and Alverson, 1959; Miller and others, 1978; Scott and Upchurch, 1982). Although the number of zones and their exact lithology vary greatly from place to place, the Hawthorn generally consists of a basal calcareous unit, a middle clastic unit, and an upper unit that is a highly variable mixture of clastic and carbonate rocks. The middle and upper parts of the Hawthorn everywhere contain more phosphate than the lower calcareous unit. Hawthorn phosphorites are mined over a large area in central Florida and are locally exploited in Hamilton County in northern Florida. Although there is some disagreement about the exact environment of deposition and mechanism of concentration of the phosphate minerals in the Hawthorn, the consensus is that the phosphate was deposited from upwelling, cold marine waters (Riggs, 1979; Miller, 1982a).

There is much local variation of rock types within the Hawthorn. Some Hawthorn clay beds contain abundant diatom remains (Miller, 1978). Palygorskite (attapulgite), a magnesium-rich clay that is useful because of its absorptive properties, is mined from the upper part of the Hawthorn in Gadsden County, Fla., and Decatur County, Ga. (Weaver and Beck, 1977). In southwestern Florida, there are thick sequences of light-gray silty to argillaceous limestone in the upper and lower thirds of the formation. In Seminole and Orange Counties, Fla., the Hawthorn is very thin and consists of beds of shell material bound together by light-gray calcareous clay. Southeast of Tampa, Fla., the uppermost part of the Hawthorn consists of brown, orange, and red clayey, slightly phosphatic sand. In northeastern Georgia, Hawthorn beds consist mostly of green silt and clay and interbedded white limestone and fine- to coarse-grained sand.

Because of its heterogeneity and the predominantly fine textured nature of both the clastic and the carbonate beds within the Hawthorn, the entire formation constitutes a low-permeability rock sequence. Where it is present, the Hawthorn Formation comprises most of the upper confining unit of the Floridan aquifer system.

The Hawthorn Formation is considered by most workers to be of middle Miocene age, and it is so regarded in this report. However, fauna are sparse within the Hawthorn, and the exact relations between this formation and the complex Miocene section of panhandle Florida are unclear at present. Parts of the Hawthorn may be as old as early Miocene or as young as late Miocene. Most of the unit, however, appears to be of middle Miocene age.

Alum Bluff Group

West of longitude 85° W, or approximately at the Apalachicola River in eastern panhandle Florida, the Hawthorn Formation passes by facies change into the lower part of a thinly bedded, complex, finely to coarsely clastic, often highly shelly sequence of strata called the Alum Bluff Group (pl. 2). Several formations have been identified within this group, chiefly on the basis of work done in outcrop areas and in the shallow subsurface. For the most part, these formations are thin and of limited areal extent, and are in many cases not well defined. More detail on the Miocene of panhandle Florida is presented in reports by Puri (1953a), Puri and Vernon (1964) and in a collection of papers edited by Scott and Upchurch (1982).

The Alum Bluff Group as used in this report refers to a sequence of gray to green clay and medium- to coarse-grained sand beds that locally contain much carbonized plant material or mollusk shells. Beds of middle and late Miocene age have been reported from the Alum Bluff Group, but no age separation within the group has been made in this study. Alum Bluff beds grade westward into coarse gravelly sands and thin clay interbeds in westernmost Florida and southwestern Alabama. Alum Bluff Group equivalents in southern Alabama are an undifferentiated sequence of gray clays and fine- to medium-grained sands. Local, patchy erosional remnants of upper Miocene beds that occur at scattered places in parts of peninsular Florida are equivalent to the upper part of the Alum Bluff Group but are undifferentiated in this report.

Depositional environments

The mollusk-rich, cast-and-mold limestone of the Tampa represents a remnant of the carbonate bank environment that characterized the Florida peninsula throughout most of Tertiary time. The Tampa was deposited in warm, shallow, clear, open marine waters in a basin that received little or no clastic supply.

The Hawthorn Formation was deposited under conditions quite different from those that existed in the early Miocene. Hawthorn sediments were laid down in shallow to moderately deep (inner to middle shelf) marine waters in a basin that received copious amounts of clastic material. The highly phosphatic and siliceous (diatom rich) beds of the Hawthorn, as well as some of the microfauna recovered from the formation, show that the waters in the Hawthorn sea were colder than those in which older Cenozoic units were deposited. The considerable local relief on the Hawthorn sea floor (Miller, 1982a) was a factor in the deposition and concentration of some of the Hawthorn phosphorites.

The Alum Bluff Group was deposited in shallow, warm to temperate waters, mostly in a marginal marine environment. Some of the gravelly sands that are part of the Alum Bluff Group in westernmost Florida may be of fluvial origin.

TERTIARY AND QUATERNARY SYSTEM: POST-MIOCENE ROCKS

GENERAL

All beds in the study area that are younger than Miocene are grouped together in this report and mapped as a single unit. Post-Miocene strata can generally be divided into a basal sequence of marginal to shallow marine beds overlain by a series of sandy marine terrace deposits that are in turn capped by a thin layer of fluvial sand and (or) residuum. The basal beds having a marine aspect are mostly of Pliocene age, the terrace deposits were laid down during the Pleistocene, and the fluvial and residual materials are of Holocene age (pl. 2). There are two major exceptions to this general post-Miocene sequence. In southern Florida, practically all post-Miocene strata are of shallow or marginal marine origin and comprise a complex and highly variable sequence of thin formations whose relations are best known along the southeastern coast. In southwestern Alabama and the westernmost part of the Florida panhandle, post-Miocene rocks are mostly a thick sequence of coarse-grained, fluvial, gravelly sands that locally contain interbedded clays, mostly near the base of the sand sequence.

The top of post-Miocene rocks has not been mapped because the surface of the unit obviously is the same as the present-day topographic surface in the study area, and the configuration of this surface is available from other published sources. The general thickness of post-Miocene rocks is shown on plate 14. This map has been contoured on the basis of well data alone, in contrast with the thickness maps of the older units discussed in this report. The purpose of plate 14 is to show the locations of the larger thickness variations in the post-Miocene unit rather than detailed changes. Over most of the study area, post-Miocene sediments are less than 100 ft thick and in many places form a surface veneer that is only 10 to 50 ft thick. In southwestern Alabama, thick Pliocene fluvial deposits make up most of the 1,400-ft-thick sequence of post-Miocene rocks found there.

PLIOCENE SERIES

Pliocene deposits in western panhandle Florida and in southwestern Alabama are assigned in this report to the Citronelle Formation. The Citronelle is a thick, mostly fluvial unit that consists mainly of medium to coarse sand containing many stringers of gravel and a few thin clay beds. There is much iron oxide in the formation, along with minor amounts of organic material. It is possible that the upper part of the Citronelle is Pleistocene in age (Marsh, 1966) but the entire formation is placed in the Pliocene in this report. The Citronelle thins to the north and east, and, if it is present outside southwestern Alabama and western Florida, it cannot be distinguished from younger terrace deposits.

Pliocene rocks in much of central Florida are represented by the Bone Valley Formation, a highly phosphatic sequence of sand and clay beds that locally contains a vertebrate fauna of Pliocene age. The extent and thickness of the Bone Valley are uncertain because the unit is difficult to distinguish from the underlying Hawthorn Formation in places. In southeastern Florida, the Tamiami Formation, a white to cream limestone that contains much sand in pockets and as admixed material, is of Pliocene age. The Tamiami and the Bone Valley are not connected. The Caloosahatchee Formation overlies the Tamiami in southern Florida. In scattered places in central and northern peninsular Florida, thin patches of shallow marine rocks are probably Caloosahatchee equivalents. The Caloosahatchee and its equivalents consist of a thin sequence of interbedded clay, calcareous clay, and sand that locally contains much broken shelly material. The upper part of the Caloosahatchee is of Pleistocene age (pl. 2).

The Raysor Formation of southwestern South Carolina is a bluish-gray, shelly, calcareous sand unit of Pliocene age that extends into northeastern Georgia. Beds now called Raysor were formerly included in the Duplin Formation of northeastern South Carolina, but Blackwelder and Ward (1979) showed that the Raysor is a separate unit. The Goose Creek Limestone (Weems and others, 1982) is a sandy, phosphatic, shelly limestone of Pliocene age that is found locally in South Carolina. The relation between the Goose Creek and the Raysor is not known at present (1984) since the two units have not been found in contact. In southeastern Georgia, the Charlton Formation, a dark brownish-green, soft, fossiliferous, locally micaceous to phosphatic clay, represents the Pliocene Series.

PLEISTOCENE SERIES

Over most of the study area, Pleistocene rocks consist of medium- to coarse-grained, tan, white, and brown sand that locally contains trace amounts of carbonaceous material and broken shell fragments. These sands underlie a series of poorly defined to well-defined terraces that are thought to have formed during the Pleistocene Epoch as seas rose and fell in response to glacial and interglacial episodes (MacNeil, 1950). There is little agreement on the number of these terraces, however, and it is possible that some of the higher ones represent pre-Pleistocene deposits (Healy, 1975). In this report, all the terrace materials are considered to be Pleistocene.

In southwestern South Carolina and northeastern Georgia, the sandy terrace deposits are locally underlain by red and yellow sands that contain thin beds of shell and stringers of phosphate. These strata are equivalent to the Waccamaw Formation of northeastern South Carolina. In southeastern Florida, Pleistocene strata consist of a series of thin and variable marine to marginal marine deposits whose relations are complex. Several highly permeable clastic and carbonate Pleistocene units, taken together, comprise most of the Biscayne aquifer, an important source of water in southeastern Florida. For purposes of this report, separate Pleistocene formations are not delineated in southern Florida. Detailed studies on the Pleistocene of southern Florida include reports by Parker and Cooke (1944), DuBar (1958), and Puri and Vernon (1964).

HOLOCENE SERIES

Holocene deposits in the study area include thin sand and gravel deposits that are mostly adjacent to present-day streams and dune, estuarine, and lagoonal sediments contiguous to the modern coast. Residuum developed from the weathering of older sediments and local windblown materials are also included in the Holocene. Holocene strata are not mapped separately in this report, nor are the different Holocene depositional environments delineated.

DEPOSITIONAL ENVIRONMENTS

Pliocene rocks in southeastern Florida (Tamiami and Caloosahatchee Formations) were deposited in shallow to marginal marine environments. The Bone Valley Formation of central Florida is mostly of fluvial origin and is comprised largely of material reworked from underlying Miocene rocks (Puri and Vernon, 1964). The Citronelle Formation of southern Alabama and westernmost Florida represents a thick sequence of fluvial beds. The Raysor and Charlton Formations of South Carolina and easternmost Georgia were deposited in lagoonal to estuarine conditions. The Goose Creek Limestone was laid down in a shallow marine (inner shelf) environment.

Pleistocene rocks throughout most of the study area represent a series of constructional sandy marine terraces deposited at the shoreline of a fluctuating Pleistocene sea. The Waccamaw Formation equivalents in South Carolina and the complex series of Pleistocene units in southeastern Florida represent marginal marine depositional conditions. All Holocene materials in the study area are either of fluvial origin or derived from the weathering of older rocks.

AQUIFERS AND CONFINING UNITS

GENERAL

The ground-water system beneath the study area generally consists of two major water-bearing units; a surficial aquifer and the Floridan aquifer system. In most places, a low-permeability sequence of rocks herein called the upper confining unit of the Floridan aquifer system separates the Floridan from the surficial aquifer. The Floridan is everywhere underlain by low-permeability rocks that are called the lower confining unit of the Floridan aquifer system in this report.

The surficial aquifer consists mostly of poorly consolidated to unconsolidated clastic rocks (except for southeastern Florida, where it is composed of limestone). Most of the water within the surficial aquifer occurs under unconfined conditions. The Floridan aquifer system's upper confining unit, which lies between the Floridan and the surficial aquifer in many places, consists mostly of low-permeability clastic rocks.

The Floridan aquifer system is a more or less vertically continuous sequence of generally highly permeable carbonate rocks whose degree of vertical hydraulic connection depends largely on the texture and mineralogy of the rocks that comprise the system. The high permeability is only rarely vertically continuous. Flowmeter data from scattered wells show that the aquifer system usually consists of several very highly permeable zones, which generally conform to bedding planes and which commonly are either solution riddled or fractured. These zones, which contribute most of the water to wells, are separated by rocks whose permeability ranges from only slightly less to considerably less than that of the high-yield zones. Because the aquifer system (and its upper and lower confining beds) is defined primarily on the basis of permeability, both the top and the base of the system as mapped in this report are composite surfaces that locally cross formation and age boundaries. Accordingly, the time- and rock-stratigraphic units that make up the aquifer system and its contiguous confining beds vary widely from place to place.

Over much of southern Florida, the aquifer system consists of several relatively thin, highly permeable zones isolated from one another by relatively thick sequences of low-permeability rocks. Differences in the hydraulic heads the several highly permeable zones and differences in the quality of the water that they contain show that the zones behave essentially as separate aquifers.

The Floridan aquifer system's lower confining unit consists of either low-permeability clastic rocks or evaporite deposits. The Floridan is everywhere underlain by these relatively impermeable strata, which separate the high-permeability carbonate rocks from older, deeper aquifers that are mostly of Cretaceous age.

SURFICIAL AQUIFER

A surficial aquifer containing water under mostly unconfined or water-table conditions is present throughout all of the study area except for those places where the Floridan aquifer system or its overlying confining bed is exposed at land surface. The surficial aquifer consists predominantly of sand, but gravel, sandy limestone, and limestone are important constituents in places. Where surficial deposits are thick, highly permeable, and extensively used as sources of ground water, they have been given aquifer names, such as the Biscayne aquifer in southeastern Florida and the sand-and-gravel aquifer in westernmost panhandle Florida. Figure 6 shows the extent of the Biscayne and sand-and-gravel aquifers, which grade laterally into widespread but thin sands that are called simply a surficial aquifer.

The term surficial aquifer as used in this report refers to any permeable material (other than that which is part of the Floridan aquifer system) that is exposed at land surface and that contains water under mostly unconfined conditions. The surficial aquifer may be in direct hydraulic contact with the Floridan or